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Battelle
Columbus Division

Probable Levels of R&D Expenditures in 1985

Forecast and Analysis

This report, from the Columbus Division of Battelle Memorial Institute, is based upon a continuing study of U.S. expenditures for research and development. It was prepared in the Applied and Technical Economics Department by Drs. Jules J. Duga and W. Halder Fisher. Parts of the data presented here were derived from such sources as the National Science Foundation, the McGraw-Hill surveys, and others.

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PROBABLE LEVELS OF R&D EXPENDITURES IN 1985

SUMMARY OF FINDINGS

1. Battelle forecasts that the total U.S. expenditures for R&D will be $107.3 billion during calendar year 1985. This is an increase of 10.6 percent over the $97.0 billion that the National Science Foundation (NSF) estimates actually will be spent in 1984.

2. Costs of performing R&D are expected to rise almost 6.5 percent from 1984 to a 1985 index level of 242.55 (1972 = 100 percent), absorbing a considerable amount of the increased funding. However, this implies a *real* increase in expenditures of approximately 3.8 percent, reaching a new peak in total real funding of R&D (Figure 3).

3. Federal government funding in 1985 is expected to be about $48.7 billion (45.4 percent of total), an increase of $4.4 billion (10.0 percent) from 1984. Performance of R&D by the Federal government will represent $11.9 billion (11.1 percent), an increase of $1.1 billion (10.2 percent) over 1984 estimates.

4. Industrial funding in 1985 is expected to be approximately $55 billion (51.3 percent of total) representing an increase of $5.63 billion (11.4 percent) over that of 1984. Performance of R&D by industry is expected to rise to almost $80 billion (74.5 percent of total), an increase of $7.9 billion (11 percent) over 1984.

5. Estimates of Federal versus industry support for the R&D performed by each of several broad industrial sectors are included in the 1985 forecast. Drawing upon historic trends, the anticipated total performance by the industrial sector has been distributed, first, within each of 17 major industrial groups, and then according to whether that performance is supported by Federal or industrial funds. These estimates are shown in Table 4.

6. In 1985, the Federal government is expected to support slightly more than three-fourths of the aerospace industry's R&D activity, one-third of electrical machinery communications and more than one-fourth of rubber products. All other broad manufacturing industry classes are expected to be supported primarily by industry funds. These ratios range from 83 percent for fabricated metals and ordnance up to 100 percent for the textile, paper, and the food and beverage industries. Overall, 32.2 percent of industrial R&D will be Federally funded with the remainder (67.8 percent) funded by industry.

7. Academic and other nonprofit institutions taken together are expected to fund $3.58 billion of R&D in 1985 (3.34 percent of total) and to perform $15.4 billion (14.4 percent). Both of these figures represent significant increases in the percentage of support and performance over the 1984 NSF estimates. These figures also include the Federal support to Federally Funded Research and Development Centers which are managed by individual universities or consortia.

8. Within the nonprofit category, colleges and universities are expected to account for 68.3 percent of the 1985 funding and 80.7 percent of the R&D performance, a small but important difference from the 1984 NSF estimates.

9. The costs of R&D performance have risen steadily in all four categories (Federal, industrial, colleges and universities, and other nonprofits), with the rate of increase being driven partially by overall inflation, but primarily by the so-called "sophistication" factor.

10. The trends in real R&D effort (see Figure 3) are continuing the upward movement established over much of the past decade. Since 1974, real R&D effort has increased at a 10-year average rate of 4.20 percent, and the projections for 1985 suggest that the 11-year average rate will be slightly smaller. Battelle estimates that during the decade of the 1980s, real R&D activity will increase at an average annual rate of approximately 3 percent, tapering off slowly from the present growth.

11. Significant factors that appear to be influencing trends in the support and performance of R&D include:

    (a) Federal emphasis on defense and space programs will have a continued influence on total R&D support and the principal industrial performers; these emphases will be felt primarily in the aerospace and electronics and communications industries.

    (b) Energy-related R&D programs will continue to experience decreased Federal support, with the exception of programs characterized as having very high risk or long-term payoff; even within these categories, there is little evidence that energy is perceived as a national problem requiring Federal R&D support.

    (c) Increased industrial support of R&D may be reflecting the impact of the tax credits instituted three years ago.

(d) University self-funding of R&D is expected to continue to show real increases, partially as a result of expanded industrial "directed programmatic endowment" support of basic and applied research.

(e) Although no details are presently available, it is expected that major new funding patterns may emerge as a result of increased activity in multiple-supported industrial research programs.

12. As a special feature, the report provides a preliminary forecast of R&D funding levels in 1986. The preliminary data show the total U.S. expenditure for R&D in 1986 to be $112.1 billion (uncorrected for inflation).

ANALYSIS AND FORECAST

Since research and development (R&D)* is Battelle's prime concern, it has an intense and abiding interest both in forecasting R&D expenditures and in assessing the cumulative results of R&D activities—technological, economic, and social. Accordingly, the Columbus Division has carried on a continuing inquiry into the forces affecting R&D activities and into their sources of support. Among the tangible outputs of this research have been a series of annual analyses and forecasts of R&D expenditures, of which the present report is the latest.

The content of this analysis and forecast of the R&D situation has evolved over the years in an attempt to supply information that Battelle considers useful to the R&D community, but was not being supplied by two well-known and respected series of reports: the National Science Foundation's *National Patterns of Science and Technology Resources* and the McGraw-Hill *Annual Survey of Business Plans for R&D*.

Earlier, the NSF *Patterns* were published during the first half of each year (usually in April) and included a forecast of that same full year's R&D expenditures, by source of funds and by performer. However, since the change to the fiscal year which now begins in October, *Patterns* contains both the preliminary data for the closing fiscal year and estimates for the two preceding years. The McGraw-Hill surveys (usually published at about the same time as *Patterns*) make forecasts—the 1984 Survey (published in May) made forecasts for 1984 and 1985—but are confined to the performance of the industrial sector and do not separate Federal from industrial funding. The Battelle report, usually published in December, has been intended to fill in a timely manner the niche that involves especially the coming year (in this case, 1985) and industrially funded R&D. Other relevant information, gleaned from many sources, also has been included.

Beginning with the 1980 forecast, we also have included a forecast of industrial R&D expenditures by broad industry class, along with the estimated distribution of those funds between industrial and Federal sources. This added feature provides the background necessary to an understanding of the way in which Federal policy can affect industrial innovation, can spur industrial support of its own R&D efforts, and can enhance the longer-term international competitiveness of U.S. industry. Although related aspects of productivity, training and manpower needs, tax incentives, balance of payments, and other concerns are not predictable, we anticipate that continued analysis of this subject will help identify both the promises and the problems associated with industrial responses to future opportunities.

Continuing the practice initiated in the 1984 Forecast, estimates are presented which cover a *two*-year forecast, to 1986.

Historical Trends in R&D Funding and Performance

Although the NSF data series goes back to 1953, we begin our analysis with 1960. Even that year represents ancient history so far as the forces currently affecting R&D are concerned. The NSF data from 1960 through 1984 are shown in Table 1.

In 1960, NSF surveys indicated that approximately 64.6 percent of all R&D supportive funds were provided by the Federal government; 33.4 percent were provided by industry; and 1 percent each came from the academic community and from other nonprofit organizations.

Between then and 1984, Federal funding rose to 66.5 percent in 1964, and has slowly declined to 45.7 percent.** Over that same time period, industrial funding declined to 31.2 percent in 1964 and has risen to 50.9 percent in 1984, with a small increase to 51.3% expected in 1985. The two

*The National Science Foundation's definitions of R&D are given in the Technical Appendix to this report.

**Note that NSF data for 1983 and 1984 are "estimated". However, comparisons among the series of *Patterns* reports reveals that adjustments are made on earlier years' figures, with such adjustments carrying back as far as 1977. Thus, many of our calculations that are dependent on long-term figures will vary from one year to the next.

nonprofit sectors have risen gradually, colleges and universities to 2.2 percent and other nonprofit to almost 1.6 percent, although these percentages have declined over the past four years.

Generally, recent trends suggest a continued increase in industry funding as a percent of total funding, with a corresponding decline in Federal sector contributions. The extent to which this behavior will continue will rest largely upon the posture assumed by the Administration, the industrial response to Federal initiatives, and the general state of the economy.

Although the Federal government had been the major *source* of R&D funds from 1953 to 1979, its dominance has been eroded since 1980. Industry is by far the major *performer* of R&D. Federal performance of R&D rose from 12.7 percent in 1960 to 16.1 percent in 1972 and has been fluctuating since that year, albeit with a generally decreasing percentage. Industrial performance reached a high point of 79 percent in 1957, and drifted steadily downward to a low of 68.6 percent in the early 1970's; more recent trends suggest a slow increase in the proportion of industrial performance, rising to over 74 percent. While the academic community's performance varied between 6 and 8

TABLE 1. SOURCES OF R&D FUNDS AND PERFORMERS OF R&D, UNITED STATES, CALENDAR YEARS 1960-1984

(Millions of Current Dollars)

		Sources of Funds				Performance[a]			
Year	Total R&D	Federal Gov't	Industry	Colleges and Universities[b]	Other Nonprofit[c]	Federal Gov't	Industry	Colleges and Universities	Other Nonprofit[c]
1960	13,523	8,738	4,516	149	120	1,726	10,509	1,006	282
1961	14,316	9,250	4,757	165	144	1,874	10,908	1,173	361
1962	15,394	9,911	5,123	185	175	2,098	11,464	1,374	458
1963	17,059	11,204	5,456	207	192	2,279	12,630	1,611	539
1964	18,854	12,537	5,887	235	195	2,838	13,512	1,904	600
1965	20,044	13,012	6,548	267	217	3,093	14,185	2,103	663
1966	21,846	13,968	7,328	304	246	3,220	15,548	2,345	733
1967	23,146	14,395	8,142	345	264	3,396	16,385	2,594	771
1968	24,605	14,929	9,005	390	282	3,494	17,429	2,868	814
1969	25,631	14,895	10,010	420	306	3,503	18,308	2,950	870
1970	26,134	14,992	10,444	461	337	4,079	18,067	3,072	916
1971	26,676	14,964	10,822	529	361	4,228	18,320	3,216	912
1972	28,477	15,808	11,710	574	385	4,590	19,552	3,383	952
1973	30,718	16,399	13,293	613	413	4,762	21,249	3,701	1,006
1974	32,864	16,850	14,878	677	459	4,911	22,887	3,888	1,178
1975	35,213	18,109	15,820	749	535	5,354	24,187	4,396	1,276
1976	39,018	19,914	17,694	810	600	5,769	26,997	4,876	1,376
1977	42,782	21,594	19,629	888	671	6,012	29,825	5,450	1,495
1978	48,129	23,876	22,450	1,037	766	6,811	33,304	6,342	1,672
1979	54,933	26,815	26,081	1,200	837	7,417	38,226	7,296	1,994
1980	62,618	29,451	30,911	1,323	933	7,632	44,505	8,306	2,175
1981	71,912	33,402	35,989	1,523	998	8,425	51,858	9,304	2,325
1982[e]	80,317	37,053	40,528	1,683	1,053	9,141	59,011	9,740	2,425
1983[e]	87,678	40,328	44,350	1,860	1,140	10,228	64,600	10,275	2,575
1984[e]	96,975	44,270	49,375	2,080	1,250	10,800	72,000	11,375	2,800

Source: National Science Foundation, *National Patterns of Science and Technology Resources*, 1984, NSF 84-311

(a) The R&D performance of Associated Federally Funded Research & Development Centers (some administered by industry, some by colleges and universities, and some by other nonprofit organizations) has been combined with that of the administering institutions.

(b) As sources of funds, these include state and local government funding.

(c) All other nonprofit institutions.

(d) Preliminary figures provided by NSF.

(e) Estimated by NSF.

percent prior to 1960, there has been a slow but steady increase in the percentage of R&D performed in this sector, with recent proportions around 12 percent. Over the past few years (since 1980) this sector's share has been declining slightly. For most of the 1960-80 period, other nonprofits, including Battelle, have grown from 2 to about 3 percent of the total, again with recent declines in that share.

It should be noted that Federal funding supports research performed by all four sectors. Currently, almost one-fourth goes to support intramural R&D; over half goes to industry; approximately one-fifth goes to colleges and universities; and the rest, slightly more than 4 percent, goes to other nonprofits. Industry absorbs almost all of its own funds, either intramurally or by contract with other industrial performers; its contracts and grants to colleges and universities slightly exceed those to other nonprofit institutions. Other nonprofits finance both themselves and the academic institutions about equally, while colleges and universities absorb all the funds that they originate.

In Table 1 we summarize the latest NSF time series on the sources of R&D funding and on the volumes of R&D performance. During the interval since 1960 total R&D dollars (not adjusted for inflation) have increased more than seven-fold. Federal funding has multiplied by a factor of five and Federal performance has increased by a factor of 6.2. In terms of constant dollars, total R&D expenditures have increased by 86 percent during 1960-84, and Federal performance has increased by 36 percent (see Table 6). Using the same deflator for Federal funding that we used for total expenditures, real Federal funding increased by about 31 percent.

Also noteworthy is the high ratio of academic performance to academic funding. In the later years of this period, colleges and universities have provided about one-sixth of the total support of their own R&D activity, with the remainder coming primarily from the Federal government.

Beginning in 1968, there was a distinct change in the rate of growth in R&D, manifested by a leveling in current-dollar Federal funding. This phase of the recent past seems to have ended with 1971, when current-dollar expenditures resumed an accelerating growth trend more nearly like that before 1968. More recent trends suggest a continued growth of total real R&D support.

The continuing transition in the support and performance of R&D, to which we referred in the 1983 and 1984 forecasts and analyses, has had a significant impact on the patterns within the overall R&D enterprise. The Federal government has developed and maintained -- albeit over the strong objections of both academia and some industry -- a posture that has influenced the type and extent of Federal support. There is perhaps no stronger evidence of this than the major restructuring of Federal programs in energy and social services. In each of these cases, it has not been merely the change in Federal *actions* that have impacted the research community, but it is more the change in *philosophy* which has permeated the scene.

In general, the more conservative philosophy has been willing to stand up to the pressures of single focussed interests and pursue fundamental postures of independence from central government actions. This has been evidenced in the encouragement of R&D within the private sector, the determination to let the marketplace decide the most fruitful areas for private investment, and the return to the sub-national levels of government those functions which are deemed most appropriate for State or local action.

The strongest Federal actions, as we shall see in later sections of this forecast and analysis, remain in those areas that are of fundamental concern to the central government: (1) national defense; (2) technological competition from our trading partners; (3) health; and (4) the environment for economic growth. The extent to which Federal actions can influence these areas will continue to be dependent upon a number of different factors, including the response to military and or diplomatic tensions throughout the world, and the pervasive question of the massive national debt.

Forecast for 1985

During calendar year 1985, Battelle expects the total current dollar volume of R&D activity to be higher than the level estimated by NSF to be achieved in 1984. A comparison of Battelle's 1985 forecast with the last available NSF estimates for 1984 is shown in Table 2. The 1985 forecast is shown in its historical setting in Figure 1.

Referring to Table 2, we estimate total 1985 R&D volume to be $107.3 billion, a 10.6 percent increase over the NSF estimates for 1984. It is expected that much of this increase will be absorbed by continued inflation (which we estimate to be 6.5 percent from 1984 to 1985 for R&D).

In connection with this forecast, there are several important factors that must be recognized. First, the total current-dollar projected increase includes an inflation factor that depends significantly on the inflation rate as it specifically applies to R&D. As will be noted in the discussion of the Cost of Research Index, this inflation factor is funda-

mentally different from that associated with the more familiar consumer price index.

In addition, it is apparent that concerns over the Federal budget will influence the remaining appropriations bills for the 1985 Federal budget. Furthermore, since part of the calendar year 1985 will come during the next fiscal year (1986), the budget process throughout this current calendar year will have a continuing effect on total expenditures.

Finally, industrial support for R&D will continue to be impacted by previous years' sales and earnings and should be expected to increase at a substantial rate. However, if industry expects that the tax credit for incremental R&D will in fact expire as originally intended, it is conceivable that the recent rate of growth of industrially-supported R&D will decrease.

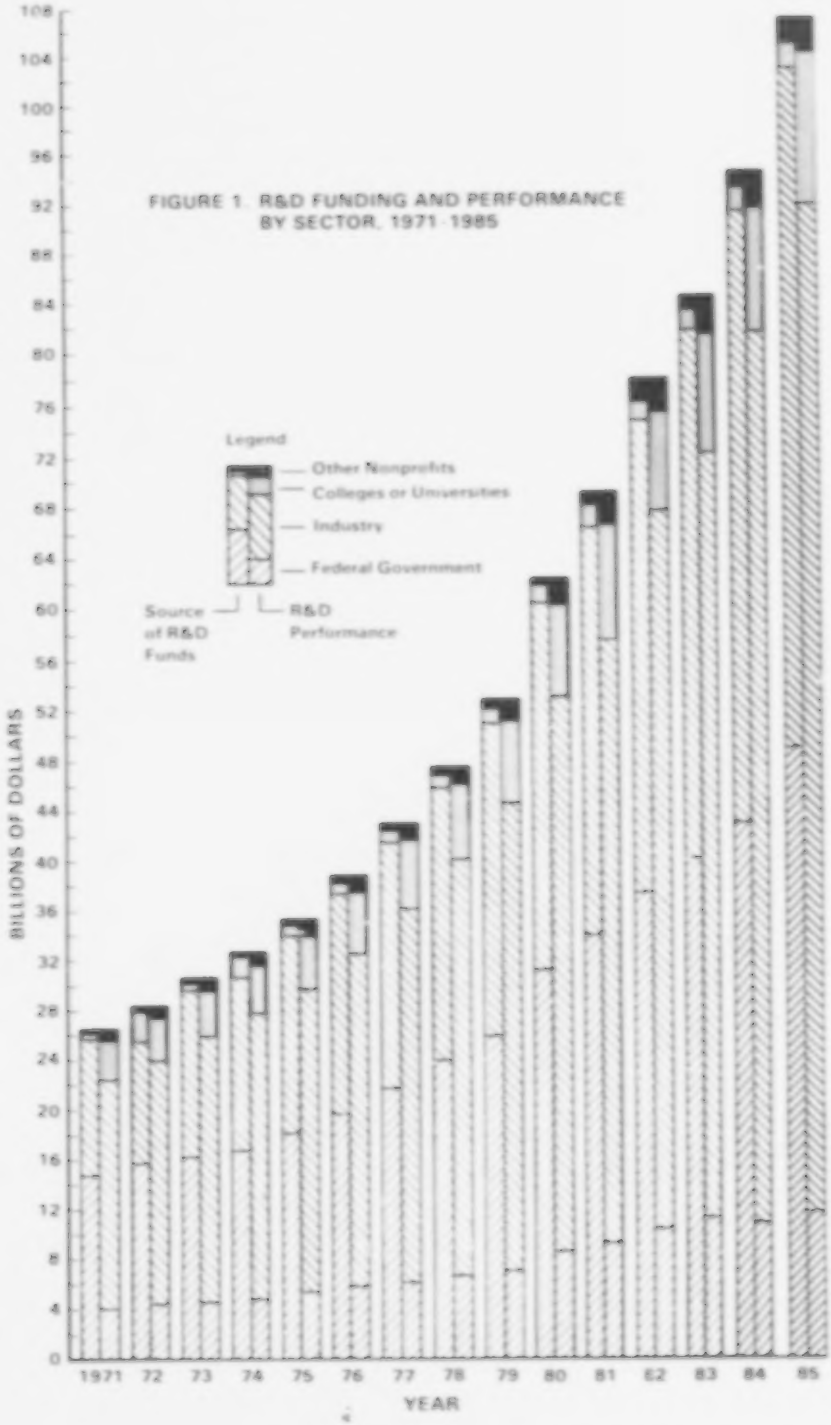
In using Table 2, the reader should keep clearly in mind all the distinctions made by the table headings. For instance, in the *column* headed "Industry", we see that the total amount of R&D expected to be performed by industry in 1985 will be $79,950 million. Of this, $25,770 million will be funded by Federal agencies, and $54,180 million by industry. On the other hand, the *row* headed "Industry" indicates that industrial sources of funds are expected to support about $55,000 million of R&D. Of this, $54,180 million will be performed by industry, $495 million by colleges and universities, and $325 million by other nonprofit organizations.

Continued inflation is expected to characterize 1985, although the rate, as experienced in R&D, appears to be declining. In addition, there are many intangibles -- partly the increased feeling on the part of both Federal and industrial decision-makers that R&D is vital to long-term eco-

TABLE 2. ESTIMATED R&D EXPENDITURES BY SOURCE OF FUNDS AND BY PERFORMERS, U.S. CALENDAR YEARS 1984 AND 1985

(Millions of Current Dollars)

Source of Funds		Performer: Federal Government	Performer: Industry	Performer: Colleges and Universities	Performer: Other Nonprofit	Source Totals: Dollars	Source Totals: Percent of All Funds
1984 NSF Estimates							
Federal Government		10,800	23,350	8,270	1,850	44,270	45.65
Industry		—	48,650	425	300	49,375	50.92
Colleges & Universities		—	—	2,080	—	2,080	2.14
Other Nonprofit		—	—	600	650	1,250	1.29
Performer Totals	Dollars	10,800	72,000	11,375	2,800	96,975	
	Percent	11.14	74.25	11.73	2.88		100.00
1985 Battelle Forecast							
Federal Government		11,890	25,770	9,065	1,975	48,700	45.39
Industry		—	54,180	495	325	55,000	51.27
Colleges & Universities		—	—	2,275	—	2,275	2.12
Other Nonprofit		—	—	625	680	1,305	1.22
Performer Totals	Dollars	11,890	79,950	12,460	2,980	107,280	
	Percent	11.08	74.53	11.61	2.78		100.00
Percentage Increases Over 1984 Estimates							
Federal Government		10.09	10.36	9.61	6.76	10.01	
Industry		—	11.37	16.47	8.33	11.39	
Colleges & Universities		—	—	9.38	—	9.38	
Other Nonprofit		—	—	4.17	4.62	4.40	
Performer Totals		10.09	11.04	9.54	6.43	10.62	

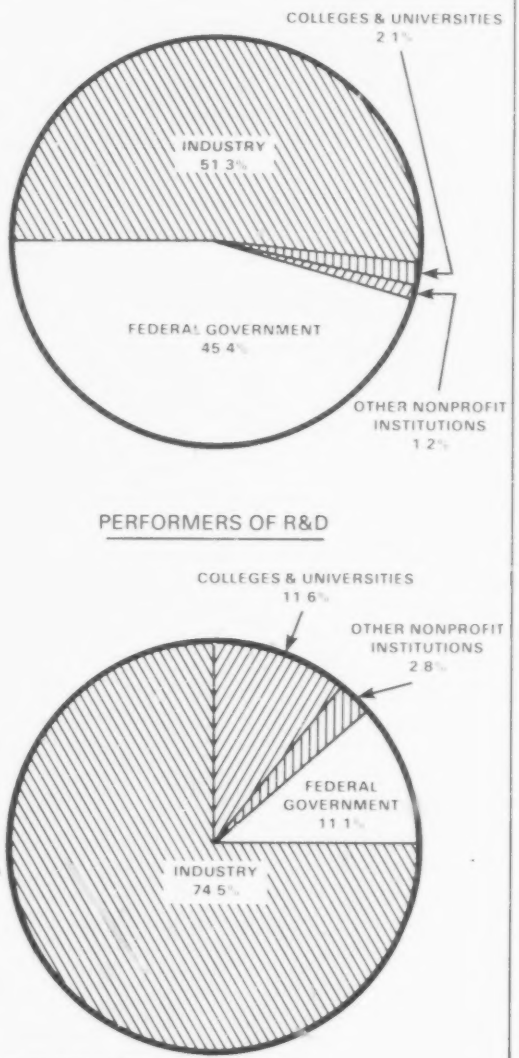


See Tables 1 and 2. 1971-1984 estimates by NSF; 1985 projected by Battelle's Columbus Division.

nomic health—that favor continued increases in support. The NSF estimated that current dollar R&D activity rose by 10.6 percent from 1983 to 1984; we project a similar increase, 10.62 percent, from 1984 to 1985. As will be shown in connection with the Cost of R&D Index, not all of this increase is expected to be absorbed by inflation.

FIGURE 2. R&D EXPENDITURES IN THE U.S., CALENDAR YEAR 1985

The total forecast by Battelle's Columbus Division is $107.3 billion. Distribution shown here is by source and performance.



Source: Battelle's Columbus Division

With respect to the *composition* of R&D activity, the expected pattern continues to be one of year-to-year stability or very slow change—with defense, science- and technology-based problems, considerations of economic development, and foreign competition—still providing the major impetus for change. The proportionate composition of both funding and performance will change very little. The Federal government will account for 45.4 percent of the total funding, as against 51.3 percent for industry. Industry will account for approximately three-fourths of total performance. These two distributions for 1985 are summarized in Figure 2.

The Role of Federal Agencies

Since Federal funding was historically the major source of R&D support (although it has been increasingly outdistanced by industrial support since 1980), the forces likely to affect Federal R&D budgets in Fiscal Years 1985 and 1986 are important in the present forecast. The Budget for Fiscal Year 1985, which began on October 1, 1984, is entirely a product of the Reagan Administration. It exhibits major departures from prior trends and sets the stage for what may be significant changes in subsequent years.

The significant increases in defense spending—in terms of both hardware and research—will be continued by the Administration's commitment to new weapons systems. Furthermore, Budget plans through 1987—while certainly subject to modification in the future—set a direction that suggests continued emphasis in this area, although perhaps with a decline in the rate of growth.

Battelle projects $48.7 billion as the most likely level of Federal funding in calendar year 1985. This figure is based upon: (a) recent trends in Federal budgeting, as reflected in NSF data series on R&D funding; (b) the relationship between Federal funding and Federal obligations; (c) the fact that three calendar quarters' funding will be determined by the FY 1985 appropriation; and (d) a strengthening of selected mission agency activities*.

The R&D-Minded Agencies

The big-money agencies in terms of total 1985 R&D funding will include the Department of Defense (DOD), the National Aeronautics and Space Administration (NASA), the Department of Energy (DOE), and the Department of Health and Human Services (HHS). Among

*Note that this estimate applies only to spending for the *performance* of R&D, and does not include any spending for R&D *facilities*.

the smaller agencies, the important suppliers of funds for extramural R&D are the NSF, the Department of Agriculture (DOA), the Environmental Protection Agency (EPA), the Department of the Interior (DOI), the Department of Commerce (DOC), and the Department of Transportation (DOT). Estimated shares for the conduct of R&D in the early proposed budgets for FY 1985 and comparative estimates of the FY 1984 plans are:

	1984 Estimated Authority	1985 Planned Authority
DOD	61.8 percent	66.3 percent
DOE	10.6	9.1
HHS	10.9	9.4
NASA	6.5	6.3
NSF	2.8	2.7
DOA	2.0	1.7
DOT	1.1	0.9
DOI	0.9	0.7
DOC	0.8	0.5
EPA	0.6	0.5

It is obvious from this listing that DOD continues to dominate the Federal scene, accounting single-handedly for almost two-thirds of the R&D budget. The Big Four (DOD, NASA, DOE, and HHS) account for 91.1 percent of anticipated Federal R&D expenditures. The next six largest R&D-supporting agencies account for only 7.05 percent, and all others combined account for approximately 1.8 percent.

These percentage distributions reflect the continuing impacts of the Reagan Administration. The 1985 structure is still subject to modification by the Congress, although no significant changes are expected.

Functional Categories

Although some of the important R&D agencies are primarily devoted to a single function, many are multifunctional. The NSF utilizes a master list of 17 functional categories, of which the most important have the following shares of estimated 1983–1985 budget authorities:

	1983*	1984**	1985**
National Defense	64.3	66.0	70.2
Health	11.1	10.8	9.3
Space Research and Technology	5.5	5.2	5.1
Energy	6.7	5.8	4.6
General Science	3.9	3.9	3.7
Transportation	2.3	2.5	2.2
Environment and Natural Resources	2.5	2.2	1.7
Agriculture	1.9	1.7	1.5
All Other	1.9	2.0	1.7

*Actual
**Estimates

The remaining functional fields, each receiving less than .5 percent of the total R&D budget, are: education, training, employment and social services; community and regional development; international affairs; veterans' benefits and services; commerce and housing credit; income security; administration of justice; and general government. Altogether, these smaller fields account for only 1.7 percent of the total.

As had been expected in earlier forecasts, the major increase in R&D expenditures will be confined to that in support of national defense. There will be some modest increases in other areas, and slight increases in many agencies or functional areas. However, as a fraction of *total* Federal R&D, almost all agencies and functional areas — except for defense — will show relative (real) declines.

The continued increase in defense-related R&D derives from the development and acquisition of more advanced major weapons systems, and the Administration's commitment to highly sophisticated space-deployed defensive approaches. While the future of such research may well depend upon the types and outputs of arms-control negotiations that recently have been resumed, we expect that the research will continue as a part of the "bargaining-chip" process.

The potential deployment of space-situated defensive weapons will have some influence on the overall space R&D program. As was noted in last year's forecast and analysis, the R&D budget for NASA was undergoing change, much of which resulted from the *operational* classification of the Space Shuttle. However, with the emphasis on defensive weaponry and — perhaps more important — the

initiation of work on the proposed Space Station, the overall NASA Program will most likely begin to garner a higher proportion of the total Federal R&D budget.

From 1969 70 to 1973 74, year-to-year changes in R&D budgets favored civilian programs over defense space. Beginning with 1974 75, emphasis has tended to shift back toward defense and space, especially the former. Throughout the 1970s, the funding of energy-related R&D generally grew by larger increments than that of space or of most other civilian programs. It is generally expected that Federally-supported energy-related research and demonstration programs will continue to decline, except for that portion which is in support of direct national defense interests. Some existing DOE programs may be transferred to other agencies, especially if efforts to combine DOE with the Department of the Interior continue, and those which involve short-term and or low-risk R&D probably will have to be financed by private industry.

Factors Affecting Future Federal Support

There appears to be a continuing effort on the part of the Federal government to increase its funding of R&D, in terms of both support to basic national needs and the broadening of the technological base on which future growth is predicated. National security, reflected in the DOD budget, is seen as a principal driving force in furthering R&D spending. Economic growth, founded upon both basic and applied research, is expected to remain as an objective which requires direct and indirect Federal support, although greater emphasis will be directed toward the latter.

The Federal efforts in energy research will continue to be based primarily on those of basic research that are either inappropriate for industrial support, at this time, or represent such long-term investments that no industrial applications are expected in the near future. As new energy technologies – either in generation or conservation and use – are reduced toward practice, there will be a greater encouragement of industry to take up the effort.

Additional emphasis on high-energy basic physics research may be forthcoming, with plans for the next generation of particle accelerators already under way.

While there are indications that industrial support will be growing in the biological sciences (as is evidenced by the major increases in industrial funding at universities), the Federal government will continue to commit substantial resources toward this and allied fields. Budget-trimming efforts, especially as they apply to both health and agriculture, have been largely cosmetic in recent years; these have been generally offset by Congressional actions that have reinstated various programs in these areas.

Over the past few years, there had been concern that Federal funding of R&D might shift from extramural contract grant support to intramural research performance, utilizing the capabilities of the extensive Federal laboratory network. In addition, such a concern could just as well be directed at the support of research in the Federally Funded Research and Development Centers (FFRDCs). Over the past few months, this concern has been amplified by the recommendations of the Packard Report and the report of the Grace Commission. In each of these cases, some consideration had been given to the "efficiency" of such operations. As of this writing, no actions have been taken in response to either of these investigations, although it is expected that some changes in laboratory operations might be forthcoming.

In viewing the trends in support of the Federal laboratories and the FFRDCs, as shown below, there is little evidence that any shift from extramural programs had been made through 1984. Furthermore, it would be anticipated that any such changes would be relatively small, and slow in coming.

The shares in Federal funding of both the truly intramural and the (university-operated) FFRDCs have, in fact, been declining over the past few years, as shown below:

Percentage of Federal Funds Expended

	Federal Laboratories	Federal Laboratories and University-Operated FFRDCs
1978	28.5	35.7
1979	27.7	34.9
1980	25.9	33.5
1981	25.2	32.8
1982	24.7	31.4
1983	25.4	31.8
1984	24.4	30.7

Continued effort is being made to "sell" the capabilities of the Federal laboratories as resources available to both the Federal and non-Federal markets. As in the recent past, there are conflicts among the various factors that may influence the ultimate outcome of this effort. While Federal regulations permit considerable involvement by Federal laboratories in response to external needs, there also are several real and perceived restrictions. Whether the Federal laboratories will be more heavily involved in R&D per-

formance as a result of actions taken in response to PL 96-480, is yet to be seen. As of this writing, there is little evidence that, taken as a whole, the Federal laboratories are heavily involved in "external" activities*. To the extent that they are, there are no reliable statistics which would support any conclusions regarding the support (on a reimbursable basis) or performance of R&D outside the laboratories specific missions.

The Role of Industry

NSF data indicate that industrial support has been greater than Federal support since 1980 and Battelle projects industrial support of R&D to be greater than that from the government in 1985. As has been the case in all previous years, industry will be by far the predominant R&D performer.

During 1984, the NSF has estimated that industry will provide 50.9 percent of total funding and perform 74.2 percent of all R&D work (see Table 2). Battelle's forecast for 1985 changes these shares almost imperceptibly to 51.3 and 74.5 percent, respectively.

TABLE 3. SECTORAL GROWTH RATES IN FUNDING AND PERFORMING R&D, 1975-1984

Sector	1975 = 100.0% Source	Performer
Total United States	273.4	273.4
Federal Government	244.5	201.7
Industry	312.1	297.7
Colleges & Universities	277.7	258.8
Other Nonprofit	233.6	219.4

Source: Derived from Table 1.

The NSF data base indicates that industry also has been the fastest growing sector. Table 3 compares sectoral growth rates for the nine-year interval 1975-84. In connection with this table, attention is called to two relationships. First, every sector tends to grow somewhat slower as a performer than as a source of funds.** And second, in the case of the government, the fact that this differential exists also indicates a lack of support for the thesis that Federally funded R&D is being transferred to Federal laboratories.

Battelle projects considerable differences among the 1984-85 sectoral growth rates. Total R&D expenditures are expected to grow by 10.6 percent; industrial funding and performance are both expected to increase by 11.4 and 11.0 percent, respectively. These represent the highest growth rates among the funding and performing sectors.

Industrial funding is expected to rise from an NSF estimated level of $49,375 million in 1984 to $55,000 million in 1985. Industrial performance will rise from $72,000 million to $79,950 million. As will be seen later, this total performance implies a definite increase in *real* industrial R&D activity (4.76 percent).

Industrial research, as it applies to the accomplishment of industrial and governmental objectives, is both a means to an end and an end in itself. While the continuing profit motive in a competitive marketplace spurs R&D for individual industry's benefit, so also does the industrial system provide a mechanism for the execution of programs of high national priority. In view of: (a) the continuing emphasis on innovation; (b) the application of advanced control technology to mature industries; and (c) continued tax incentives for industrial R&D, Battelle's 1985 forecast continues a new area of analysis, namely, the comparative Federal and industrial funding of R&D in major groups of industries.

Using data derived both from NSF sources and from interpolation or extrapolation of the McGraw-Hill surveys, we have estimated the degrees to which industrial and Federal funds will support industry R&D performance (see Table 4).

This distribution between Federal and industrial funds is, unfortunately, somewhat misleading for it does not address the more critical question of support of R&D among different lines of business. With R&D expenditures grouped according to major SIC classifications, it is not possible to distinguish, for example, electronics research performed by a well-known electronics company from that performed by a subsidiary of a major company whose principal product line (and SIC classification) falls into an entirely different category. Conversely, this determination does not isolate, for example, research in chemicals which is performed within the rubber or petroleum industries.

With reference to Tables 2 and 4, the performance of R&D by industry will be financed either by the Federal

*The roles and operations of the Federal laboratories may be influenced by the recent Packard Report (and the Federal agency response) as well as the expansive report of the Grace Commission.

**Although this appears to be a mathematical anomaly, it results from substantial differences in the two weighing patterns.

government or by industry itself. Industrially funded work will mostly be done by industry either internally or contracted to other industry, although a very small amount (less than 2 percent) will be done extramurally by universities and other nonprofit institutions. The nonmanufacturing industries do relatively little R&D and, as noted in Table 4, approximately 40 percent of the support for this activity is provided by the Federal government. In contrast, R&D is more heavily self-funded by (and in) the manufacturing industries where, on the average, about 32 percent of the total performance is supported by Federal funds.

The leading industry in the nation for R&D will be the aerospace industry, projected to do approximately $20 billion, with over three-fourths of its funds from Federal sources. In second place will be the electrical machinery and communications industry, projected to spend almost $17 billion, of which 33.5 percent is Federally funded. Since 1980, these two major sectors have dominated and interchanged between first and second place and are expected to dominate in the foreseeable future. Further appropriations for defense systems, as well as anticipated growth in the computers and communications industries, are expected to continue the dominance of these two broad industrial classes.

Aside from aerospace, where Federal support of R&D is dominant, there are no industry groups in which more than half of the R&D performance is expected to be supported by Federal grants and contracts. In addition to electrical machinery and communication and rubber products (28.3 percent), no other industries receive as much as 18 percent of their funding from Federal sources.

Finally, we call attention to the fact that the total industry fundings shown in the third column of Table 4 make no distinction between R&D performed in-house or that contracted out to academia, to nonprofit organizations, or to other industrial firms.

TABLE 4. ESTIMATED SOURCES OF FUNDS FOR R&D BY BROAD INDUSTRIAL CLASSES, 1985

(Millions of Current Dollars)

	Federal Funds	Industry Funds	Total Funds	% Federal
Aerospace	$15,144	$ 4,868	$20,013	75.67
Electrical Machinery and Communications	5,683	11,257	16,940	33.54
Machinery	929	8,863	9,792	9.48
Chemicals	510	8,433	8,944	5.70
Autos, Trucks & Parts, & Other Transportation Equipment	826	6,382	7,208	11.45
Professional & Scientific Instruments	841	4,630	5,471	15.36
Petroleum Products	229	2,355	2,584	8.86
Rubber Products	422	1,071	1,493	28.26
Food & Beverage	0	944	944	0.00
Fabricated Metals & Ordnance	146	675	821	17.76
Stone, Clay, & Glass	13	583	596	2.21
Paper/Pulp	0	596	596	0.00
Iron & Steel	8	488	497	1.69
Nonferrous Metals	27	380	407	6.70
Textiles	0	158	158	0.00
Other Manufacturing	82	1,160	1,242	6.62
Total Manufacturing	24,861	52,845	77,706	31.99
Nonmanufacturing	909	1,335	2,244	40.50
TOTAL	25,770	54,180	79,950	32.23

Factors Affecting Future Industrial Support

The significant increase expected in industrial support of R&D is linked to three factors. First, the general economic climate appears to be improving and industry is responding to new opportunities foreseen in both the short- and longer-range futures. As greater emphasis is being placed on industrial productivity, revitalization, the growth of the so-called "information society", and the expansion of both consumer and industrial markets, it is anticipated that sales and profits (both early indicators of R&D fund availability) will be increasing in the near term.

Second, there has been a relaxation of (selected real and perceived) barriers to cooperative research programs, thus prompting major multiply-supported research programs at universities, and the creation of the first of what may turn out to be dedicated research centers. The general concept is, of course, not new—multiclient ("group") projects have been performed at Battelle for more than 40 years. But new impetus has been given to the concept through the encouragement of the Federal government, especially the provisions of the National Cooperative Research Act, and the magnitude of these dedicated undertakings is expected to be significantly greater than that associated with classical multisponsored programs.

Third, it appears that a portion of the increased R&D expenditures by industry may be attributed to the additional tax incentives for R&D enacted in the early days of the present Administration. Inasmuch as R&D planning by industry usually leads expenditures by one to three years, at a minimum, it was expected that the tax incentives would not have a major impact until 1983 and beyond, as noted in Battelle's 1981 forecast. It appears that the earlier prognoses are now correct. At present, effort is underway to extend the 1986 cutoff date assigned to this provision of the bill.

There remains one significant *caveat*. The extent to which the present forecast reflects an accurate picture of 1985 industrial funding will depend upon a continuing growth of the economy. In spite of some slowdowns in 1984, it appears that no major disruptions will affect sales, profits, and continued R&D spending, at least in the short term.

Two additional notes regarding industrial support of R&D should be mentioned here. Over the past few years, a slightly different mode of cooperative R&D funding has emerged: that of a "syndication" of venture capital spending which mitigates the risks associated with the reduction of research to commercialization. In many respects, this form of funding is not generically different from the cooperative support by industry which was discussed above. There are, however, two distinctions: (1) the efforts are, at this time, devoted more toward development and commercialization than to basic and applied research; and (2) the supporting participants are more often smaller investors, rather than major corporations.

Finally, there is emerging a stronger role of State government, acting both as a source of funds and as a facilitator of small "high-tech" industrial activity. Innovative State-operated programs in Pennsylvania and Ohio, for example, have resulted in the creation of new R&D-intensive companies. The total amount of State funding is, at present, quite small. However, the impact on total small business funding may, in time, be significant. This mode of new business development should be traced carefully over the next few years to assess its impact.

The Role of Academic and Other Nonprofit Institutions

Nonprofit institutions—colleges, universities, and other types—both fund their own research and conduct research funded by Federal agencies and or industrial firms. It is generally conceded that a significant portion of all basic research is conducted in this sector, as well as some of the longer maturing applied research.

In 1960, the academic and other nonprofit institutions financed from their own resources (including endowments and direct state and local funds) approximately 2 percent of all R&D (see Table 1), while actually performing over 9 percent of the total. For 1985, Battelle forecasts (see Table 2) that these same nonprofits will provide 3.3 percent of all funding and will perform 14.4 percent of the total.

These percentages are slightly lower than the corresponding ratios for the 1984 NSF estimates. Both academic and other nonprofit performers will experience increases in funding, but barely in line with the projected inflation rate.

The growth in nonprofit R&D performance has been accompanied by minor shifting within the nonprofit sector. In 1960, the academic community (universities and colleges) accounted for 55.4 percent of total nonprofit funding and performed 78.1 percent of the nonprofit total. For 1985, Battelle forecasts 63.3 percent and 80.7 percent, respectively. A significant portion of the increase in academic support and performance derives from the increase in "directed endowments", discussed elsewhere in this forecast.

Attention is called to the part played in these developments by the nonacademic nonprofit organizations. There are two distinct groups of these "other" nonprofit organizations, the *foundations* which exist primarily for charitable purposes and the *nonprofit research centers* which may or may not perform under contract. The first group funds a great deal of research, primarily through the mechanism of grants; and these grants go both to members of the academic community and to other nonprofit centers. The second group acts in three ways: a member may perform as a foundation; it may fund its own research performance; and/or it may perform under contracts (with government, industry, or other nonprofits).

From 1965 to 1980 other nonprofit performance has fluctuated slightly between 3.3 and 3.7 percent of total R&D. Since then, this sector has declined to less than 3 percent. For 1985, Battelle estimates that the other nonprofit sector will comprise 2.78 percent of total R&D performance. Furthermore, we estimate that 47.9 percent of other nonprofit funding will go to colleges and universities, with the remaining 52.1 percent being spent by the other nonprofit sector itself. This division of support is approximately the same as that estimated by NSF for calendar year 1984.

The total R&D performance in the other nonprofit sector is not increasing as rapidly as in other performing sectors. However, a word of clarification is appropriate. As noted above, this sector is quite diverse in the character of the constituent organizations. As performers of R&D, the establishments within this sector range from institutions such as Battelle (engaged in a broad spectrum of programs in the classic science and technology fields as well as in economics and other social sciences) to small nonprofit firms that act as delivery mechanisms and research arms for Federal, state, or local government agencies, especially for social programs.

The activities of these latter types of organizations have been significantly curtailed in recent years. Hence, it is not unexpected that the aggregate of nonprofit performers should display smaller-than-average growth rates, or, in fact, real declines in comparison with other performing sectors.

It also should be noted that historical data for the other nonprofit sector has some serious shortcomings, especially with regard to recent years. The NSF has not conducted detailed surveys of nonprofit funding and performance for quite some time. The recent data are no better than "estimates based upon estimates", and forecasts developed from such data have similar uncertainties.

Finally at this point, attention is called to the variety of forms taken by industrial support for academic R&D. In addition to contracts or grants to support research on industrial problems (this is the "industry funding of colleges and universities" shown in Table 2) there is another form of support, not yet reported in detail by the NSF, that must be noted. These industry–university arrangements take a form that more nearly resembles a "directed endowment" rather than either a specific research contract or a general gift. The large multiyear programmatic grants are then accounted for in terms of college and university self-funding.

Although major endowments of universities or individual departments may accomplish objectives that are important both to academia and to industry, not all such partnerships have been completely welcomed. On the positive side, these major programs may foster advanced university research and industrial access to faculty and graduate students. Furthermore, they provide a mechanism for promoting further graduate research and education—countering a trend that has been disturbing to both the universities and industry.

On the other hand, there has been some reluctance toward the development and concentration of university research programs in areas closely tied to potential commercial ventures. The academic community may be willing to develop patents and possible commercial spinoff industry, but there is certainly less enthusiasm for creating situations in which external forces might dictate department policy. Industrial reluctance for these arrangements derives from the difficulty of maintaining proprietary claims and confidentiality with respect to the findings of industrially sponsored research. The slow, but continuing, growth of this form of funding suggests that, at least to this time, the "mutual concerns" either have not developed or have been resolved.

The Cost of R&D Inputs

From an economic point of view, inflation can be defined as a general rise in the price of goods and services that is not offset by corresponding increases in quality. If the prices of everything tend to rise together, slowly, and in the same proportions—and if individual incomes also rise in those same proportions—the relations between money and goods/services change, but in a fashion which is detrimental mainly to the holders of such fixed-dollar obligations as life insurance. On the other hand, when the prices of things bought with income rise faster than the incomes, structural imbalances occur which may be quite painful to particular sectors of the economy.

Goods Versus Services

Most considerations of prices tend to take place within the context of goods' prices, i.e., the prices of tangible things. The very tangibility of goods makes it possible both to measure the quantity of their output and to estimate, within reasonable limits, changes in their quality. Thus, with respect to goods, there usually is agreement as to whether or not costs are rising faster than output, or prices faster than quality—that is to say, we tend to have general agreement that inflation is or is not occurring in the goods-related economy.

Services, on the other hand, are intangible. Therefore we usually have greater difficulty achieving agreement that, in terms of any meaningful measure, the quantity or quality of service output is rising or falling. As a result, our only measure of many types of service output is the total amount of money that we pay for them—and that is a function of price and quantity, with no account taken of quality.

R&D, by definition a part of the "knowledge industry", is primarily a service activity, despite the fact that much of it ultimately becomes embodied in products. For this reason, we have no agreement as to what can be termed a "unit" of R&D output; and we, therefore, cannot ascertain whether or not the "price" of R&D *output* is rising or falling. We can price R&D *inputs*, however, and for that reason most discussions of the cost of R&D tend to be couched in those terms. Battelle has not yet given up hope of achieving a measure of R&D output, and from time to time has undertaken investigations which may lead to the quantification of at least some kinds of R&D output. Nevertheless, such a measure is not now available and the discussion which follows must be in terms of input costs.

In viewing the costs of R&D performance, it is tempting to contrast the "inflation" in R&D with the commonly used Consumer Price Index (CPI)—the factor which provides a measure of general inflation—or to use the GNP deflator, as NSF does. To do so misses three basic points distinguishing R&D from the more general set of purchases. First, the CPI is based upon the average "marketbasket" purchased for general consumption, and the GNP deflator covers a somewhat broader range. However, purchases by R&D performers are from a much more specialized collection of goods and services.

Second, the education of scientists and engineers has a built-in bias for the acquisition and use of more sophisticated (and, hence, generally more expensive) materials, devices, and systems required for the conduct of research. Were it not for this factor of the research culture, technological advance would not be so rapid.

Third, and perhaps most important of all, the very nature of research is such that the problems addressed by researchers are increasingly more difficult. The easy questions are always solved first; and the effort necessary to make incremental gains in the understanding and application of science and technology is ever-increasing. Thus, it would be expected that the "inflation rate", as applied to the conduct of R&D, would increase more rapidly than that of the average consumer purchases.

The "Cost of R&D Input" Index

In the absence of a measure of R&D output costs, many organizations, including the NSF, use the GNP deflator (from the national income and product accounts) as an indicator of changes in R&D costs. This index responds to the costs of both goods and services. R&D costs are made up primarily of service costs, however, for which reason Battelle researchers feel that the GNP deflators probably have misstated recent rates of inflation with respect to R&D.

Several attempts have been made in the recent past to determine the input mixes of typical R&D activities and to price each input, thereby generating standard weighted price indexes for R&D. To date, this approach has not been very productive, although such efforts continue and may eventually achieve success.

A pioneering effort at more directly measuring trends and fluctuations in the cost of R&D was made by Helen Milton* beginning in 1966. Using information supplied by representative R&D performers Milton compiled data on the total dollar cost of R&D per technical (professional) man-year.** Her series of cost indexes ended with 1970, using 1950 as the base year. Between 1970 and 1979 Battelle extended the Milton Index series by means of annual estimates. Finally a new series of R&D cost indexes was introduced in the 1980 Battelle Forecast and Analysis. This new series, while conceptually similar to the Milton Series, is based upon a different body of data and does not show precisely the same year-to-year changes as the Milton Series and our earlier extensions thereof.

The Battelle Cost of Research Index, displayed in Table 5, is based upon two series regularly published by the NSF: (a) the R&D performance figures, by Sectors, that have already been discussed in connection with the Source

*See Helen S. Milton. "Cost of Research Index, 1920-1970". *Operations Research*, 20, 1: 18 (1972).

**Milton said on p. 1: "The 'technical man' is the professional scientist or engineer, plus his support".

Performer Matrix (Table 2); and (b) estimates of the full-time equivalent numbers of R&D scientists and engineers employed by each performing sector. The ratio of costs to scientists/engineers for each sector provides the basis for the sectoral subseries, which are then weighted and combined into the all-sector average.*

As derived from Table 5, Battelle's best estimates of recent increases in the total index are for 6.8 percent for 1981-82, 5.2 percent for 1982-83, and 6.5 percent for 1983-84. We expect the cost of R&D to increase by about 6.5 percent between the estimated 1984 level (227.76) and the forecast level for 1985 (242.55) with the estimates stated in terms of the 1972 base.

*As noted, in the text, the Battelle Cost of Research Index is derived from both NSF data and our own projections. Variations in the historical cost index, as reported in these Forecasts, are generally attributable to changes in the NSF data, which are continuously adjusted. Note, for example, that the *Patterns* report for 1982 contains adjustments in data dating back to 1970, and the *Highlights* report, noted earlier, contains adjustments in data dating back to 1977.

Sector Comparisons of R&D Costs

During the interval 1972-85 costs of all R&D, as an average, are estimated to have risen by 142.55 percent. Increases in the individual performing sectors are expected to be: Federal government, 148.98 percent; industry, 137.19 percent; colleges and universities, 174.30 percent; and other nonprofit, 147.24 percent. As noted, the 1984-85 cost increase for all R&D is estimated to be 6.49 percent. By sectors, the increases are estimated as Federal, 9.68 percent; industry, 6.0 percent; colleges and universities, 7.66 percent; and other nonprofits, 4.11 percent.

TABLE 5. BATTELLE COST OF RESEARCH INDEX* BY PERFORMING SECTORS, CALENDAR YEARS 1960-1985 (1972 = 100.00)

Year	Total U.S.	Performing Sectors			
		Federal Government	Industry	Colleges and Universities	Other Nonprofits
1960	59.17	49.22	62.57	46.50	72.55
1961	60.68	51.45	63.28	52.64	74.47
1962	62.89	54.81	64.64	59.25	77.11
1963	67.12	56.59	69.27	65.79	76.18
1964	71.76	67.48	72.35	73.35	75.07
1965	73.32	70.22	73.61	75.36	76.29
1966	77.09	70.59	78.17	78.78	80.69
1967	78.54	71.65	79.51	81.46	82.11
1968	81.33	72.09	82.58	85.43	86.29
1969	83.84	71.75	85.93	85.34	93.97
1970	86.43	84.78	86.05	37.66	98.94
1971	90.53	89.88	90.10	92.00	97.58
1972	100.00	100.00	100.00	100.00	100.00
1973	109.09	105.55	109.89	110.53	104.71
1974	116.51	109.37	118.19	115.22	120.42
1975	120.89	120.19	120.33	123.17	127.04
1976	130.13	128.47	129.96	132.01	134.08
1977	137.46	133.46	137.15	142.53	142.64
1978	148.20	148.85	145.53	161.63	153.14
1979	161.64	160.59	158.25	181.93	166.03
1980	174.27	163.48	171.68	200.62	181.11
1981	190.44	179.10	187.84	217.90	197.18
1982	203.36	193.58	201.30	226.50	209.54
1983	213.91	215.79	210.34	234.92	221.67
1984	227.76	227.01	223.76	254.78	237.47
1985	242.55	248.98	237.19	274.30	247.24

*Costs of performing R&D per scientist/engineer (full time equivalence).

Source: Estimated by Battelle from NSF and Battelle data.

Trends in Real R&D Effort, by Sectors

If we take total expenditures and sector performance figures from Tables 1 and 2 and deflate them to constant 1972 dollars with the corresponding index numbers from Table 5, we can make parallel comparisons for each of the four performing sectors. These are shown in Table 6 and graphed in Figures 3 and 4.

In current (undeflated) dollars, total U.S. R&D expenditures have risen in every year of the period, even though the rate of increase fell sharply between 1969 and 1971. But the deflated (real effort) series before 1978 reached its peak in 1969, declined between 1969 and 1973, and moved generally sideways until 1977, when it exceeded $30 billion for the first time in 10 years. We expect real R&D effort in 1985 to increase by 3.8 percent over 1984 and to reach a level that is 44.6 percent above its 1969 peak.

When we shift our attention to the performing sectors, we find that the recent upward drift of real R&D activity results from the behavior of the private sector. The downturn or flat behavior in real expenditures that began after 1968-69 is clearly reflected by every sector. However, deviations in sector behavior emerged later, especially since about 1975. In government, the real performance series has

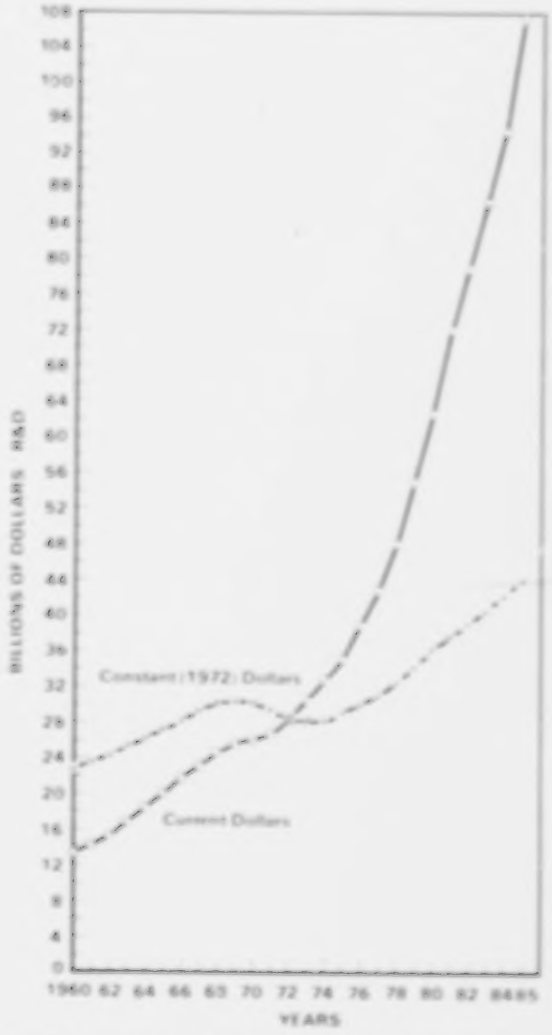


FIGURE 3. TOTAL R&D EXPENDITURES, 1960-85, IN CURRENT DOLLARS AND CONSTANT DOLLARS (1972 = 100%)

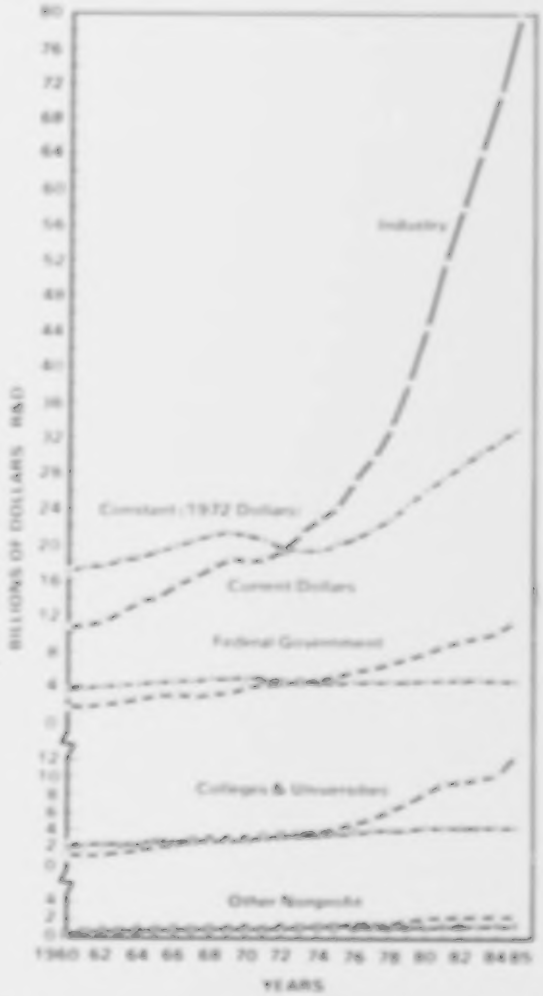


FIGURE 4. R&D EXPENDITURES BY SECTORS, 1960-85, IN CURRENT DOLLARS AND CONSTANT DOLLARS (1972 = 100%)

recovered only slowly from its 1974 minimum and has not yet equalled its 1969 peak.

In the private sectors, industry reached its real low in 1973 and has since risen by 74 percent to its highest recorded value. The academic community reached its low in 1973. Since then, its real performance has risen by almost 36 percent and now stands well above the 1968 value. Other nonprofit institutions' real performance declined from 1968 through 1970. Since that time it has risen by 30 percent to a level of 28 percent above the 1968 peak.

Finally, we turn to the data of Table 6 and the curves of Figures 3 and 4 to see the dramatic differences in the R&D trends among the four performing sectors. Since the lull of the early 1970s, industrial performance, funded by both government and industry, has been largely responsible for the real growth within the R&D enterprise. Using the same performance deflators as applied to the sources of funds, it is seen that over the past decade, industrial support of R&D has increased at an average compounded rate of 5.84 percent per year, while Federal support has increased at 2.64 percent per year on average.

The behavior exhibited in Figures 3 and 4 suggests that the real growth in R&D — and the economic development and expansion that result from it — has come from the applied research supported and performed by private industry. However, one cannot overlook the fact that such applied research and development must rest on, and evolve from, the basic research foundation — an activity that is primarily supported by the Federal government (almost 66 percent).

Over the past few years, Federal support has tended to shift toward more "development" and less basic and applied "research". The Federal government is still the major supporter of basic research, and trends in the Federal budget indicate that this support will continue to be strong. In addition, there is a continuation of basic research support

TABLE 6. CURRENT AND CONSTANT DOLLAR (1972 = 100) R&D EXPENDITURES IN THE U.S., 1960-1985, BY PERFORMERS

(All Amounts in Millions of Dollars)

	Total U.S.		Federal Government		Industry		Colleges and Universities		Other Nonprofits	
Year	Current	Constant	Current	Constant	Current	Constant	Current	Constant	Current	Constant
1960	13,523	22,854	1,726	3,507	10,509	16,795	1,006	2,163	282	389
1961	14,316	23,592	1,874	3,642	10,908	17,237	1,173	2,228	361	485
1962	15,394	24,474	2,098	3,827	11,464	17,734	1,374	2,319	458	594
1963	17,059	25,415	2,279	4,027	12,630	18,232	1,611	2,449	539	707
1964	18,854	26,274	2,838	4,205	13,512	18,674	1,904	2,596	600	799
1965	20,044	27,334	3,093	4,405	14,185	19,270	2,103	2,790	663	869
1966	21,846	28,335	3,220	4,561	15,548	19,889	2,345	2,976	733	908
1967	23,146	29,470	3,396	4,740	16,385	20,607	2,594	3,184	771	939
1968	24,605	30,251	3,494	4,847	17,429	21,104	2,868	3,357	814	943
1969	25,431	30,568	3,503	4,882	18,308	21,303	2,950	3,457	870	926
1970	26,134	30,235	4,079	4,811	18,067	20,994	3,072	3,504	916	926
1971	26,636	29,465	4,228	4,704	18,320	20,331	3,216	3,495	912	935
1972	28,477	28,477	4,590	4,590	19,552	19,552	3,383	3,383	952	952
1973	30,716	28,157	4,762	4,512	21,249	19,337	3,701	3,348	1,006	961
1974	32,864	28,207	4,911	4,490	22,887	19,364	3,888	3,374	1,178	978
1975	35,213	29,127	5,354	4,455	24,187	20,099	4,396	3,569	1,276	1,004
1976	39,008	29,975	5,769	4,490	26,997	20,773	4,866	3,686	1,376	1,026
1977	42,783	31,122	6,012	4,504	29,825	21,745	5,261	3,824	1,495	1,048
1978	46,129	32,475	6,811	4,576	33,304	22,883	6,342	3,924	1,672	1,092
1979	54,933	33,984	7,417	4,619	38,226	24,154	7,296	4,010	1,994	1,201
1980	62,618	35,931	7,632	4,668	44,505	25,922	8,306	4,140	2,175	1,201
1981	71,912	37,760	8,425	4,704	51,858	27,607	9,304	4,270	2,325	1,179
1982	80,317	39,493	9,141	4,722	59,011	29,314	9,740	4,300	2,425	1,157
1983	87,678	40,987	10,228	4,740	64,600	30,712	10,275	4,374	2,575	1,162
1984	96,875	42,577	10,800	4,757	72,000	32,176	11,375	4,465	2,800	1,179
1985	107,280	44,203	11,890	4,775	79,950	33,706	12,460	4,542	2,980	1,205

Source: Current dollar figures from Tables 1 and 2, deflated in terms of Battelle R&D Cost Index of Table 5

by industry. However, the volatility of those indicators (sales, profits, cash flow) which influence industrial R&D budgets precludes the stability needed for long-term planning. Policy- and budget-makers in all funding sectors should note very carefully the trends in basic research, for the conduct of such research forms the basis for future economic vitality and competitiveness.

Thus, the Federal government, in any attempt to maintain the vitality of our technology-based and technology-influenced economy, should continually reexamine its policies relative to (a) the support of R&D, (b) the roles of the private and public sectors, (c) the factors which enhance or impede the progress of science and technology, and (d) the commitment to science education at all levels.

A Look Toward 1986 and the Future

While former issues of the Battelle *Forecast and Analysis* (through the 1983 edition) had been confined to consideration of just the forthcoming year, well-established commitments by both the Federal government and industry permit a preliminary longer look at the R&D forecast. Judging from recent trends in government spending, long-term budget authorities, and the existing overall business climate, it is estimated that 1986 sources for R&D will be:

Federal government	$ 50,890 million
Private industry	57,480 million
Colleges & Universities	2,380 million
Other Nonprofit Organizations	1,360 million
TOTAL	$112,110 million

In addition, it is estimated that 1986 expenditures of R&D will be distributed among the four performing sectors as follows:

Federal government	$12,400 million
Private industry	83,570 million
Colleges & Universities	13,020 million
Other Nonprofit Organizations	3,110 million

The overall 4.5 percent increase in funding and performance (expressed in constant 1985 dollars) will be spread almost evenly among the various sectors, although industrial funding and performance could surge ahead at a somewhat greater pace. The driving forces for such greater industrial activity would come from both the Federal commitment to defense/space programs and the continuance of healthy sales and profits in the private sector.

Federal funding, over the past few years, has been dominated by major increases in the defense budget, including both the expansion of existing hardware and the design and development of future systems. Looking to the near-term future, and considering Congressional unrest over the deficit, we expect that the growth in R&D will continue, but that the rate of growth will slow somewhat. This slowing will come almost completely from the defense area (there are few other areas remaining that could survive substantial cuts).

Industrial funding of R&D also will grow, although there might be significant differences within the industrial sector. The past few years have seen substantial increases in industrial support, with much of this having been spurred by a general expansion of the economy, the realities of foreign competition, and, to a lesser degree, the tax incentives. As we approach 1985 and beyond, there is evidence that small high-technology companies will continue to grow, but that there will be a winnowing out in many areas. Already, the field of biotechnology shows indications of the loss of the numbers of participating companies, and many in the field of personal computers and other electronic instruments have found the competition to be far greater than originally anticipated.

As performers of R&D, additional impetus is being given to university/industry partnerships and the establishment of cooperative centers of excellence. Through the programmatic efforts of Federal and State governments, initiatives are being taken to enhance the environment for R&D and the concomitant industrial development.

While the basic philosophy of the present national Administration favors a hands-off attitude toward industrial R&D, the actual practice of this policy is far from "pure". To be sure, there is a significant difference between policies that "help" and those that "permit". Present Federal attitudes seem to be divided between both approaches. On the one hand, "help" is provided through matching support, especially that which stresses small or start-up businesses. Conversely, "permission" is granted through a relaxation of real or perceived barriers to cooperative programs. Throughout all of this Federal action, there lie the hypotheses that (1) small businesses account for a disproportionate share of innovation, and (2) the economic expansion (and profitability) that can be achieved by letting the marketplace define survivability will result in enhanced competitiveness and increased tax revenues. Each of these hypotheses, if realized, is expected to have beneficial effects on the pervasive budget deficit problems. It remains to be seen whether this philosophy and approach will accomplish the desired goals.

The trends in Federal spending show a continued increase in the amount of investment in all categories of basic research, applied research, and development. The overall philosophy of R&D funding by the Federal agencies appears to have taken strong roots: specifically, the opinion that research support by the central government should be confined to those areas where that government has prime (or perhaps unique) responsibility, such as national defense, and in areas where private investment cannot be expected to be sufficient, as in high-risk long-term projects or those characterized as being so truly basic that no commercial applications are obvious. In addition, the spectrum of support continues to be largely confined to the so-called "hard sciences" (both physical and biological) and engineering, with little support for the "soft" sciences.

As would be expected, there is continued support for research emphasizing the exploitation of scientific and technological information, especially as it impacts on the strength of the U.S. economy. On the other hand, there is little support for those programs addressing the non-technological factors relating to the future impacts of technology. To be sure, science education programs that suffered during the early years of the Administration show some signs of recovery. However, much has yet to be done to provide the kinds of incentives necessary to retain or maintain strong educational programs in the pre-college area.

The total support of R&D involves an obvious "partnership" between government and industry in terms of both the levels of support and the division among basic research, applied research, and development. Industry is expanding a previously uncharacteristic role in the support of basic research, primarily through significant programmatic support at universities. In addition, the relaxation of anti-trust regulations reduces the reluctance for cooperative research, in both basic and applied sciences.

In addition, the development of technologies that have obvious applications in defense, space, health, and other Federal agenda items, have (and have had) significant implications in terms of industrial growth and competitiveness. Thus, there are continuing efforts (such as implementation of the Stevenson-Wydler Act, PL 96-480) made to promote greater cooperation between Federal laboratories and the private sector.*

In the non-Federal government sector, there has been emerging a greater emphasis on the support of R&D, especially the "development" portion that leads toward commercialization. Over the past few years, State governments have initiated programs ultimately aimed at economic development. While previous efforts had emphasized the roles of the universities and the creation of the so-called "Centers of Excellence", more recent emphasis has been placed on partnership programs, linking universities with small industry, technological entrepreneurs, and venture capital sources.

Some of this State (and, to a lesser extent, Local) government support is actually directed toward the development and commercialization of R&D-based products and processes, in contrast with previous efforts at merely encouraging business development. Similarly, a portion of the efforts has been directed toward the creation of new industry and the retention of existing industry. Both of these approaches are in sharp contrast with the classical "raiding" approaches that had been previously emphasized. At present, the total budget for this type of activity is quite small, compared with the national totals of R&D; furthermore, there are no recent data indicating the total magnitude of this funding or the trends that might be developing. As suggested earlier, this form of funding may never grow to be large, but it may act as a catalyst for industrial and venture capital sources for R&D, as well as for substantial economic development.

The national commitment to continued support and growth of R&D is based upon the (usually non-quantifiable) observation of the positive impacts of past actions. Each funding and performing sector — individually and in concert with the others — has made major contributions to the economic strength and security of the nation. Furthermore, this cooperative effort has permitted the assumption of a pre-eminent position among the nations of the world.

But as technological advances are made, a greater effort should be pursued to look at the long-term implications of R&D and its applications. There are many difficult questions that must be addressed, including considerations of the educational system, the potential displacement of skilled and unskilled laborers alike, the impacts of increased life expectancy, and the general changes in the delivery of all manner of goods and services. Government and business alike have a responsibility to take the longer view, to assess the impacts of technological change, and to develop alternative postures that can assure that the benefits of technological change can be realized without serious disruption to the society.

* The extent to which these efforts have paid off is less than had been anticipated or hoped; in many respects, the lack of "success" relates to a lack of understanding of the incentives of both the providers (Federal laboratories) and the users (private industry). One should not, of course, take this to be an indictment of either side of the exchange process.

TECHNICAL APPENDIX

NSF DEFINITIONS OF RESEARCH AND DEVELOPMENT

Many activities, from one viewpoint or another, may be termed "Research and Development". The National Science Foundation (NSF) has, since its inception, been concerned with both the definition and the measurement of R&D. We probably can do no better than again quote the most recent definitions that the NSF has evolved. By these definitions, we can say:

"*Research and development* . . . consist of basic and applied research in the sciences (including medical sciences) and in engineering and activities in development . . .

"*Research*, which encompasses both basic and applied, is systematic, intensive study directed toward fuller scientific knowledge of the subject studied.

"*Basic research*. For three of the sectors – federal government, universities and colleges, and other nonprofit institutions – the definition of basic research stresses that it is directed toward increases of knowledge in science with . . . a fuller knowledge of understanding of the subject under study, rather than a practical application thereof. To take account of an individual industrial company's commercial goals, the definition for the industry sector is modified to indicate that basic research projects represent . . . original investigations for the advancement of scientific knowledge . . . which do not have specific commercial objectives, although they may be in fields of present or potential interest to the reporting company.

"*Applied Research*. The following is the core definition in the NSF questionnaire sent to the universities and colleges: "*Applied research* is directed toward practical application of knowledge". Here again, the definition for the industry survey takes account of the characteristics of industrial organizations it covers ". . . research projects which represent investigations directed to discovery of new scientific knowledge and which have specific commercial objectives with respect to either products or processes". By this definition, applied research in industry differs from basic research chiefly in terms of objectives of the reporting company.

"*Development*. The NSF survey concept of development may be summarized as ". . . the systematic use of scientific knowledge directed toward the production of useful materials, devices, systems or methods, including design and development of prototypes and processes".[*]

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[*] National Science Foundation, *National Patterns of R&D Resources, 1953 '78*, '79, NSF '78-313, p. 25.

ABOUT BATTELLE-COLUMBUS

Battelle's Columbus Division is the original contract research center of Battelle Memorial Institute, an internationally recognized nonprofit scientific research and development organization with laboratories and offices throughout the world.

Research at Battelle-Columbus encompasses virtually all facets of science and its application, including fundamental research and education. Studies are funded by small and large industrial firms; by municipal, regional, state, and Federal government agencies; and by associations and private groups in the United States and abroad. Research ranges from performing short-term, modest, problem-solving investigations to conducting and managing long-term, multidisciplinary, multimillion-dollar programs.

In conducting research, Battelle provides the sponsor with the physical facilities, equipment, and personnel on a contract basis. More than 2,000 studies in diverse fields are pursued in a typical year. Among the major research areas are electronics, biotechnology, information sciences, energy, environmental quality, resource management, applied and technical economics, health sciences, engineering and manufacturing technology, materials sciences, transportation, and national security.

Battelle-Columbus also has extensive research facilities at nearby West Jefferson, Ohio, where nuclear, life sciences, and large-scale pilot-plant studies are conducted. Other components include Battelle's New England Marine Research Laboratory, Duxbury, Massachusetts; the Florida Marine Research Facility, near Daytona Beach, Florida; Battelle's Petroleum Technology Center, Houston, Texas; and Battelle's C. F. Kettering Research Laboratory, Yellow Springs, Ohio.

The staff numbers more than 3,100 scientists, engineers, and supporting specialists whose training and expertise embrace the physical, life, social, and behavioral sciences. Research volume at Battelle-Columbus is more than $165 million a year.

Battelle Memorial Institute, headquartered in Columbus, Ohio, was established by the Will of Gordon Battelle. The Institute has as its broad objective the benefit of mankind by the advancement and utilization of science through a broad range of research, development, and demonstration programs, as well as educational, and invention and technology development activities. In helping to meet the challenges of today, its goal is to advance knowledge through research and other creative scientific activities and to apply that knowledge to improve the quality of life. In addition to conducting sponsored research for others, Battelle maintains its own research, development, educational, and invention-development programs.

Research operations at Battelle began in 1929 with a staff of 30 people. Today, the staff numbers more than 7,400 worldwide and research volume is in excess of $480 million annually. Battelle operates major research facilities in Columbus, Ohio; Richland, Washington; Geneva, Switzerland; and Frankfurt, Germany. Additionally, it has offices and correspondents in various cities in the United States, Europe, Latin America, Australia, and the Far East.

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